THE ENDOGENOUS LEVEL OF CALCIUM METABOLISM AS AFFECTED BY VARIOUS FACTORS

BY

JOHN HARWOOD LONGWELL

B.S., in Agriculture, University of Missouri, 1918

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AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ANIMAL HUSBANDRY IN THE GRADUATE SCHOOL OF THE UNIVERSITY OF ILLINOIS, 1941

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I. INTRODUCTION

Because of the important role which calcium plays in the animal body, a large number of investigations on many phases of calcium metabolism have been carried out. Although the importance of a knowledge of the endogenous level of calcium metabolism is recognized by many investigators, a very limited amount of research directly planned to answer the many questions relative to endogenous calcium has been reported.

The metabolism of the inorganic nutrients probably differs materially from that of the organic nutrients. The products resulting from the catabolism of the organic nutrients are useless or, in some cases, toxic, and are eliminated from the body. The simple compounds and ions, which appear in the metabolism of the inorganic nutrients, probably are as available to the tissues as are similar products absorbed from the intestine, and can be used repeatedly as need arises; being excreted from the body only when present in excess of the quantities required. Any losses which would occur when the intake was extremely low might be looked upon as an unavoidable waste or leakage, representing the inefficiency of the body in conserving these essential materials, when the intake falls below normal. Some evidence exists which indicates the nearly complete suppression of any endogenous calcium loss in the young, rapidly growing animal.

Calcium is unique among the inorganic nutrients in having a large and readily available reserve store in the bones, which may be drawn upon to maintain the normal levels in the blood and soft tissues when the intake is low. Calcium metabolism is also affected by a number of other factors, the main ones being the vitamin D intake, the calcium:phosphorus ratio of the diet, and the degree of activity of the parathyroid in producing parathormone.

Because of the extensive nature of a complete study of endogenous calcium, this work was limited to those phases which were considered of primary importance.

The phases of the problem which were investigated are:

1. The determination of whether or not an endogenous calcium loss actually occurs.
2. The relationship of body size to endogenous calcium loss.
3. The effect of the degree of saturation of body stores of calcium on the endogenous calcium loss.
4. The effect of the degree of saturation of body stores of calcium on the capacity of the animal to adapt itself to a low calcium intake.
5. The interchange of calcium between the intestinal lumen and the intestinal blood circulation.

II. EXPERIMENTAL

The question of whether or not an endogenous loss of calcium actually does occur was investigated by feeding rats and rabbits diets which were otherwise adequate, but which were low in calcium, 0.027 percent in the case of the rats and 0.065 percent with the rabbits, and making periodical collections of feces and urine. The calcium losses were determined by determining the amounts of calcium in these collections of excreta. When the total calcium loss remained at approximately the same level for two or more consecutive periods, the endogenous level was considered to have been attained.

The relationship of body size to endogenous calcium excretion was studied by using two species of animals, rats and rabbits, differing considerably in body size, and including rats varying in weight from 100 grams to 600 grams and rabbits from 2 kilograms to 4.5 kilograms live weight. In addition results on endogenous losses of calcium reported on pigs by Steenbock and Mitchell, and on men by Mitchell and Owen, were included in the calculations. Inclusion of these data on pigs and men made possible the calculation of relationships between endogenous calcium and body size over the range in live weight extending from 100 grams to above 100 kilograms. The ratios of endogenous calcium to live weight, surface area, and basal heat production were calculated.

The degree of saturation of body stores in rats was calculated by comparing the percentage of calcium in the bodies of the experimental rats, in some cases determined by carcass analysis, in others estimated from balance, with the percentages reported for normal rats of various weights, which had received liberal quantities of dietary calcium, reported by Sherman. The degree of saturation was expressed as a percentage of the normal, and this percentage was related to the endogenous calcium per square meter of surface area, to determine the effect of degree of saturation of body stores on the endogenous loss.

The effect of the degree of saturation of body stores of calcium on the capacity of the animal to adapt itself to a low calcium intake was investigated by observing the length of time required and the amounts of calcium lost by rats having different degrees of saturation of calcium stores while attaining equilibrium on a low calcium intake. The relationships of the degree of saturation of body stores to the time required to reach equilibrium and to the amount of body calcium lost while attaining equilibrium were used as a measure of this effect.

When rats are changed from a high to a low calcium intake, considerable amounts of calcium are lost from the body by way of the intestine for several days. Using the method proposed by Bergeim, of comparing the quantities of calcium in the food, at various places in the intestine, and in the feces, with an insoluble reference substance, the interchange of calcium between the intestinal lumen and the intestinal blood circulation was investigated.

During the course of one experiment the rats ate lead solder from the wire grids used to support them in the metabolism cages. This lead interfered with the calcium determination both in the feces and urine, and may have disturbed calcium metabolism in these rats.

III. SUMMARY AND CONCLUSIONS

The endogenous calcium in rats, rabbits, pigs and men is closely related to the surface area and to basal heat produc-

tion; the ratio of endogenous calcium to surface area being 103 mgms. per square meter, and of endogenous calcium to basal heat being 0.13 mgm. per calorie.

In rats, age is more important than degree of saturation of body stores in determining both the amount of calcium lost and the time required to establish the endogenous level of calcium metabolism on a low calcium diet. Mature rabbits require a longer time but lose a smaller percentage of their calcium stores, in attaining the endogenous level than do immature rats.

The degree of saturation of calcium stores in rats, as measured by the percent which the calcium in the body represents of the normal amount reported by Sherman, does not exert a significant effect on the amount of endogenous calcium excreted.

When rats, in which the calcium stores are nearly saturated, are changed from a high calcium intake to a low one, they conserve their calcium stores by restricting calcium excretion, eventually reaching a state of equilibrium. When the stores are depleted and the calcium intake is increased, the rats retain a high percentage of the intake until the stores are approximately saturated, when they use dietary calcium much less efficiently. When returned to a low calcium intake they again restrict the excretion, equilibrium being attained while the calcium stores retain a high percentage of calcium.

In the growing rat calcium may be reduced to approximately 0.50 percent by the body weight, but in mature rats, starting with saturated stores, and remaining at constant weight, reduction below 0.90 percent appears to be very difficult. The values represent approximately 50 percent and 85 percent of saturation in young and mature rats, respectively.

The quantity of calcium excreted is considerably in excess of the amount absorbed in the upper small intestine, in rats and rabbits, the excreted calcium probably being in the digestive juices. Calcium absorption exceeds excretion in the remainder of the small intestine and the cecum. Excretion exceeds absorption in the upper large intestine, but no change occurs in the lower large intestine.

Elementary lead, consumed by rats, interferes with the determination of calcium, both in feces and urine. However, the possibility is not ruled out that absorbed lead not only interferes with the calcium determination, but that it disturbs calcium metabolism.

VITA

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Type in Swine as Related to Quality of Pork, Bull and Longwell, Illinois Agr. Expt. Sta. Bul. 322.

Relative Economy of the Various Cuts of Pork, Bull and Longwell, Illinois Agr. Exp. Sta. Bul. 330.

Growth Studies with Swine, Longwell, Henderson, and Insko, West Virginia Agr. Exp. Sta. Bul. 230.

Effect of Soybeans and Soybean Oil Meal on Quality of Pork, Bull, Carroll, Longwell, Olson and Hunt, Illinois Agr. Exp. Sta. Bul. 336.

Some Observations on Pigs Receiving Vitamin A Deficient Rations, Longwell and Weakley, Amer. Soc. Animal Prod. Proc., 1932.

A Beef Cattle Program for West Virginia, Creech, Livesay, Wilson, Rietz, and Longwell, West Virginia Agr. Exp. Sta. Circ. 306.

Color of Lean Beef as Affected by Grass and Grain Feeding, Longwell, West Virginia Agr. Exp. Sta. Bul. 274.

A Proposed Minimum Animal Husbandry Requirement for Teachers of Vo-Ag., Longwell, Amer. Soc. Animal Prod. Proc., 1936.

Effects of Sex, Length of Feeding Period and a Ration of Ear Corn Silage on the Quality of Baby Beef, Bull, Olson and Longwell, Illinois Agr. Exp. Sta. Bul. 335.

West Virginia Pastures, Pierre and Longwell, et al, West Virginia Agr. Exp. Sta. Bul. 280.

Buckwheat Middlings as a Protein Supplement for Growing and Fattening Swine, Longwell, Amer. Soc. Animal Prod. Proc., 1928.

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BIBLIOGRAPHY

1. Bergeim, O., Intestinal chemistry. VII. The absorption of calcium and phosphorus in the small and large intestines, J. Biol Chem. 70, pp. 51-8, 1926.
2. Mitchell, H. H., Carroll, W. E., Hamilton, T. S., Garrigus, W. P., and Hunt, G. E., Calcium and phosphorus supplements for growing swine, Ill. Agr. Expt. Sta. Bul. 434, pp. 15-54, 1937.
3. Mitchell, H. H., and Curzon, E. G., The dietary requirement of calcium and its significance. Actualities Scientifique et Industrielles 771: Nutrition XVIII, pp. 1-10, 1939.
4. Owen, E. C., and Irving, J. T., The calcium requirements of older male subjects with special reference to the genesis of senile osteoporosis, Acta Media Scandinavica, 103, pp. 235-50, 1940.
5. Sherman, H. C., and Bocher, L. E., The calcium content of the body in relation to that of the food, J. Biol Chem. XCIII, pp. 93-103, 1931.
6. Steenbock, H., and Hart, E. B., The influence of function on the lime requirements of animals, J. Biol Chem. 14, pp. 59-73, 1913.